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ABSTRACT

The primary objective of this study was to compare problem solving performance among formal operational, transitional, and concrete operational individuals with the effect of relative field independence taken into account within each of these three cognitive developmental levels. Secondarily, the study explored whether a developmental relationship exists between logical thought and field independence. Eight male and eight female subjects per grade were randomly selected from class lists for sixth, seventh, eighth, and ninth grades and classified according to cognitive developmental level. All criterion problems (to be solved) are fully described. Sex and age differences are discussed. In general, the study concludes that Piagetian developmental level does provide an overall theoretical framework in which to understand and interpret differences in complex, deductive problem solving performance, but, in the problems used, field independence does not appear to clarify individual differences in a meaningful way. (TL)

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PIAGETIAN OPERATIONS AND FIELD INDEPENDENCE AS FACTORS IN CHILDREN'S PROBLEM SOLVING PERFORMANCE[1]

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The sorts of strategies an individual uses in a problem solving situation can be understood in terms of the developmental capacities he brings with him into that situation. These strategies that he is capable of dictate his approach to the problem and to a considerable extent what he is also capable of finding out. They reflect the cognitive structure or organization underlying his problem solving performance. The development of logical thought as described by Piaget (1960, 1969; Inhelder and Piaget, 1958; Flavell, 1963) is a theoretical approach that appears to satisfy some of the more crucial demands of a theory of human problem solving as suggested by Newell, Simon, and Shaw (1958; Simon and Newell, 1970). The latter contend that a theory of human problem solving should answer certain questions: does the theory (a) predict the performance of a problem solver on handling specified tasks; (b) explain how problem solving takes place; (c) show how changes in the conditions of the problem solver or of the task confronting him alter problem solving behavior; (d) explain how specific and general problem solving skills are learned, i.e., or acquired developmentally; and (e) predict incidental phenomena that accompany problem solving? (adapted from Newell et al., 1958, p. 151). With these questions in mind, the purpose of the present investigation was to study how young adolescents approach a particular kind of problem solving situation as a function of their cognitive

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developmental level. In addition, it was hypothesized that individual differences in cognitive style, in which analytic ability is emphasized, might be a second relevant variable to explore in studying problem solving behavior and pertinent to the above theoretical demands.

The specific problem solving situations used were two detective-type, mystery stories developed by Covington, Crutchfield, and Davies (1966) which were presented in booklet form, and each were scored in four categories. These problems and ones similar to them in form have been characterized as being creative in quality (Covington and Crutchfield, 1965) and as being indicative of 'productive thinking' (Wertheimer, 1945; Aschner and Bish, 1965; Olton and Crutchfield, 1969). This creative, productive view of problem solving involves organization and planfulness in tackling the problem, generation of original ideas, taking a different perspective on a problem which resists solution, sensitivity to unusual circumstances or discrepant facts, and inferring the implications of such discrepancies. It involves hypothesizing potential solutions and evaluating their possible applicability to the problem. These are, then, the skills or strategies which seem to be needed for complex problem solving, but no light is shed upon why some people are more effective problem solvers than others. What are the cognitive structures underlying these problem solving skills? This question forms the foundation of the study undertaken here.

Developmental research has been emphasized by investigators of cognitive development and by those studying the construct field independence (Witkin, et al., 1954, 1962), but little attempt has been made

to relate the two cognitive theories in intellectual functioning (Pascual-Leone, 1970). It is the author's contention that the construct, field independence, as measured by the Rod and Frame test, provides information about individual differences whereas Piagetian theory provides a general framework or structure by which to evaluate a given individual's level of cognitive development. It should be noted that with increasing age field independence tends also to increase through adolescence, but an individual's position relative to his peers on a field independence distribution is surprisingly stable across time (Witkin, et al., 1962). This trend is, however, less clear-cut for females. With regard to intellectual functioning and field independence, Witkin et al. (1962) found significant differences in favor of the field independent Ss in their performance on Duncker's (1945) "functional fixedness" problems. In a factor analysis three performance sub-tests of the WISC (a) block design, (b) picture completion, and (c) object assembly were found to be heavily loaded on the same factor, designated as the "analytic field approach", as the three perceptual tests of field independence (Rod and Frame, Embedded Figures, and Body Adjustment tests; Witkin et al., 1962). The two theories, although different in their assumptions and conceptualizations of intellectual functioning, might well have some elements in common, especially those which might be broadly classified as emphasizing analytic abilities. Bringing together the two cognitive theories in looking at problem solving behavior would seem, then, to yield more information as to how particular individuals perform as well as how group developmental

differences express themselves in problem solving performance.

With regard to the emphasis on analytic abilities, the independence end of the continuum of field dependence/independence represents relative analytic ability and the dependence end represents relative analytic inability (Witkin, et al., 1962). The characteristics of this analytic ability associated with field independence are as follows: (a) ability to overcome embedding contexts, (b) ability to separate parts from the whole and recombine them to form a new whole, (c) ability to conceptualize a (potential) situation apart from the dominant organization fo the field. These expressions of analytic ability appear to parallel several characteristics of formal operational thought as described by Inhelder and Piaget (1958) which are: (a) ability to perceive contradictions or discrepancies "embedded" in one's thought and logically eliminate them (e.g. by means of class inclusion, seriation, proportionality, etc.), (b) ability to solve problems involving several variables which must be separated from their context in order to be dealt with analytically, (c) ability to consider possible hypotheses and work out inferences based on the veracity or falsity of the hypotheses. (This parallels the ability to conceptualize a situation apart from the dominant organization of the field in that the individual can consider possibilities which are not tied to the empirical, concrete situation at hand.) This set of analytic characteristics, viewed from the cognitive style perspective and from the perspective of the development of logical thinking, can provide us with a process-oriented interpretation of how problem solving occurs; how strategies for logically dealing with problematic

situations develop, and how effective and successful problem solvers may differ in their problem solving behavior from those who are comparatively less effective and less often successful in solving complex problems.

Two Piagetian tasks were selected which require formal operations for the derivation of the law pertinent to the task. These two tasks are designated by Inhelder and Piaget (1958) as (a) "The Law of Floating Bodies" (hereafter referred to as the specific gravity task) and (b) "Combinations of Colored and Colorless Chemical Bodies" (hereafter referred to as the chemical combination task). They will be described at length in the Method section. The specific gravity task was selected for its emphasis on the resolution of contradictions and the chemical combination task for its emphasis on combinatorial thinking. The present investigation has hypothesized that in addition to possessing the cognitive structures of formal operations in order to derive the laws underlying these tasks, the individual will also be relatively field independent. Due to the unavailability of standardized norms for the field independence/dependence continuum for a sample comparable to the one used here, 10 to 15 year old children, the phrase relative field independence has been defined empirically from the data obtained in this investigation using the Rod and Frame test.

The primary objective of this study, then, was to compare problem solving performance among formal operational, transitional, and concrete operational individuals with the effect of relative field independence taken into account within each of these three cognitive developmental

levels. A secondary objective was to explore whether a developmental relationship exists between logical thought and field independence. An additional analysis was undertaken to determine the presence or absence of sex differences in field independence in terms of cognitive developmental level. This last analysis was considered necessary due to the frequent finding that females are significantly more field dependent that males (Witkin et al., 1954, 1962; Chateau, 1959; Bauermeister et al., 1963; Vaught, 1965). If the effect of sex of the subject is an important determinant of relative field independence, then it must be taken into consideration in exploring a potential developmental relationship between field independence and logical thinking.

Method

Sample

Eight male and eight female subjects per grade were randomly selected from class lists for sixth, seventh, eighth, and ninth grades, yielding a total sample size of 64. The age range was from 10,9 to 15,1 years with an average of 13,1 years.

The participating junior high and elementary schools serve an upper-middle class neighborhood and the socio-economic status represented by this sample was remarkably homogeneous. Each child was asked at the beginning of the session the educational level of both mother and father and the present occupation of both mother and father. Most mothers had had some college or had received a B.A. Most mothers were also unemployed. The break-down for fathers is as follows: (a) no college: 8, (b) some college: 9, (c) B.A. degree: 24, (d) M.A., Ph.D. or professional

degree: 23. Thus 73 per cent of the fathers of the subjects in this study had received a B.A. or graduate degree. Fathers' occupations were generally concomitent with their educational level, and those fathers who had some or no college were generally self-employed or highly skilled technicians.

Procedure

The following tasks were given to each subject: (a) Rod and Frame test, (b) Piagetian task No. 1: specific gravity, (c) Piagetian task No. 2: chemical combination, (d) Productive Thinking problem No. 1: "The Missing Jewel", (e) Productive Thinking problem No. 2: "The Old Black House". A more detailed description of the tasks and the rationale for their use follows.

Rod and Frame test. This task required the subject to make a perceptual judgment whereby the cues on which he bases his judgment are both self-generated and generated by the embedding visual field. It is the relative degree to which a person relies upon the visual context or field or upon his own internal kinesthetic cues in making his perceptual judgment, which in turn affects his performance and resulting score, indicating relative field independence or dependence.

The portable Rod and Frame apparatus is a rectangular tunnel-like box, about three feet in length, made of opaque white plastic. At one end is an opening for the subject's head, at the other end is a moveable disk on which a black frame is mounted and visible to the subject inside the box. In the middle of the frame is a moveable black rod. The experimenter tilts the rod and frame and then slowly begins to

adjust the rod to the true vertical. The subject is instructed to say 'stop' when he believes the rod to be at the true vertical. Each subject receives eight trials. His score is the mean number of degrees from the true vertical at which he sets the rod.

Piagetian task (1): specific gravity. This problem was chosen for its emphasis upon the separation of variables and elimination of contradictions, and for the necessity of hypothesizing a situation that has no empirical correlate: that is, the concrete context, some receptacle of water, must be overcome in order to conceptualize a volume of water equal to that of the floating (or sinking) object. This conceptualization requires hypothetico-deductive thought and, according to the hypothesis, a relatively high degree of field independence.

The procedure used follows that outlined by Inhelder and Piaget (1958; p. 20):

> A given number of disparate objects are presented to the subject who is asked to classify them according to whether or not they float on water. Then, (the classification completed) he is asked to explain the basis of his classification in each case. Next, the subject himself experiments, having been given one or several buckets of water; f[illegible]lly he is asked to summarize his observations.

Tape recordings of the entire exchange were made, as well as notes on behavioral phenomena. Dialogue protocols were transcribed from the recordings and notes, and two judges, the experimenter and a trained graduate student, independently scored the protocols to establish a stage rating for each subject. An 11 point scale was used to represent

subjects' progress through the stages and is presented in Table 1.

Insert Table 1 here

The percentage of agreement between the judges within a one point difference was 93%, differences were worked out in conference. The scoring procedure used follows Inhelder's and Piaget's theoretical and behavioral distinctions between stages (or periods) as described for this task in The Growth of Logical Thinking.

Piagetian task (2): chemical combination: A second formal operations problem was thought necessary because of the problem of familiarity or lack of familiarity with task content and its effect on the subject's ability to deal with the problem (see Gagne's treatment of this issue, 1969). The task of combining various chemicals to produce a colored solution was thought to be relatively unfamiliar to all the subjects, thus creating a situation in which the strategies used (e.g. operations performed) by the subjects could be evaluated apart from the influence of differential task familiarity.

The colored solution can be achieved by trial and error, but the systematic evaluation of the role each chemical plays in creating the proper yellow solution (and subsequently bleaching it) requires combinatorial thinking, which is a formal operational process. It was also predicted that those subjects who used formal operational thinking in working out this chemical analysis task would also be relatively field independent.

Task instructions followed those used by Inhelder and Piaget (1958). Protocols were made from tape recordings and notes on behavior, and the experimenter and a trained graduate student independently scored the protocols to establish a stage rating for each subject. The percentage of agreement between the judges was again noted and within a one point difference was also 93%; conferences were used to work out differences. Scoring procedures followed those outlined by Inhelder and Piaget (1958).

Productive Thinking problem (1): "The Missing Jewel". The problem facing the subject in this mystery story is to determine how a jewel was stolen from Mrs. Winthrop during a black-out which occurred during a dinner party given by herself for three other guests. The police searched all the guests and the rooms, but the jewel was no where to be found. A window was open, however, but no foot-prints were to be seen on the muddy ground below. Key clues for the subject to solve this problem are a feather found on the floor and an opened box with perforations which one of the guests had brought with him. The correct solution of the mystery is that one of the guests brought a trained bird in the perforated box into the room which he released after blacking out the lights and opening the window. This guest stole the jewel, attached it to the trained bird which flew out the window, where it presumably waited for its master, the guest.

The strategies needed for the solution to this mystery problem appear related to the cognitive processes required in Inhelder's and Piaget's formal operational problems. It will be recalled that in the chemical problem the subject must be able to analyze a solution

into its combinatorial parts. The situation facing the subject in "The Missing Jewel" is to combine the various clues presented to him in such a way that he arrives at the solution: who stole the jewel. At the beginning of the problem he is given the situational context of the theft and must be able to perceive some facts as relevant clues and other facts as irrelevant to the solution. Success in perceiving the relevant facts or clues would seem to indicate an analytic approach to the elements of the problem and thus imply relative field independence. Global perception of the situation in which the theft occurred would result in the various relevant and irrelevant clues appearing 'fused together', thereby hampering solution of the problem. Where such an approach to the problem seemed to occur, one might suspect the subject to be relatively field dependent. He would be unable to separate the elements of the problem and recombine them into a new configuration which would have led him to the correct solution.

The subjects' performance on this problem was scored in four categories: (a) number of relevant clues cited, (b) number of correct analytic choices made in the feedback units contained within the problem, (c) number of plausible ideas generated for solution, and (d) score on the solution scale of 1-5 for speed and adequacy of attainment of the correct solution ("1" represents a complete and most quickly deduced solution, "5" represents no solution).

Productive Thinking problem (2): "The Old Black House". This mystery problem requires a reorganization of the elements of

the problem. A detective is sent to investigate a supposed robbery in a deserted old black house. He stays the night with a Mr. Round, who lives next door to the old black house and who also owns several other similar houses in the vicinity. The next morning the detective awakens after a very heavy sleep to find that the black house has simply disappeared. He drives back to the main highway via a slightly different route. What has actually happened is that the detective was moved during the night in his drug-induced sleep by Mr. Round to another near-by house, also owned by Mr. Round. In order for the subject to arrive at this correct solution (and he is given a number of cues and hints) he must be able to extract discrepant or contradictory facts from their embedding context, to hypothesize a situation which is not directly or specifically given to him in the story, and finally to make inferences from his hypotheses as to how to resolve the discrepancies by considering several variables (e.g. the different return route, the very heavy sleep, and others not mentioned above). Such cognitive processes or strategies appear to coincide with the cognitive 'requirements' for solving Inhelder's and Piaget's formal operational problems. It would also appear that relative field independence is called for in being able to overcome the embedding context of the discrepancies, in being able to conceptualize a situation apart from the dominant organization of the field, and by being able to deal with the parts of the whole (viz. the elements of the problem), whereby the elements must be reorganized for the solution.

The subjects' performance was scored in four categories: (a) number

of puzzling or discrepant facts noticed, (b) number of correct analytic choices made in the feedback units contained within the problem, (c) number of plausible ideas for solution, and (d) score on the solution scale of 1-5 for speed and adequacy of attainment of the correct solution.

Results

Sex Differences

The data of this investigation were analyzed and evaluated in two main analyses of variance and one correlation matrix. In the first analysis the factor Piagetian level was nested within sex, and the dependent variable was Rod and Frame test performance. The Piagetian level of each subject was determined by combining his stage evaluations on each of the two tasks in the following manner: (a) Level I: concrete operational level; S solved both tasks using concrete operations; (b) Level II: transitional level; S solved one task using concrete operations and the other task using formal operations or in transition to formal operations; (c) Level III: formal operational level; S solved both tasks using formal operations or in transition to formal operations. The means, standard deviations, and cell frequencies are presented in Table 2.

Insert Table 2 here

The main effect of sex on the Rod and Frame test revealed significant differences ($F=5.67$, $p<.02$). The nested part of the design showed a

significant F for Piagetian level only within the girls for the Rod and Frame test between the formal operational level and the transitional level for girls ($F=7.30$, $p < .009$). For the boys Piagetian level was not a significant factor affecting their performance on the Rod and Frame test.

The effect of sex was analyzed on Piagetian task performance, using as the dependent variables the separate stage ratings for the chemical task and the specific gravity task. The F value obtained was not significant.

Problem Solving Performance

The second main set of analyses focused upon the central issue of the study: can problem solving performance be understood in terms of cognitive development and a field independent (analytic) approach or 'style'. The statistical design with cell frequencies for this multivariate analysis of variance is represented schematically in Table 3.

Insert Table 3 here

Field independence level was determined by ranking the Rod and Frame test scores for all subjects with the resulting distribution divided into thirds. Field independence level was then nested in Piagetian level, and a multivariate analysis of variance was undertaken on the eight dependent variables from the two Productive Thinking problems. Table 4 contains the means for this analysis.

Insert Table 4 here

This analysis revealed a significant multivariate F (F=2.17, $p<.01$) for the main effect of Piagetian level on problem solving performance. Post hoc contrasts using ~~θ~~s (the multivariate analog to Scheffé contrasts) were calculated to establish confidence intervals, but no one of the eight dependent variables alone statistically differentiated the Piagetian groups, rather together they formed a function for which the Piagetian level was significant. Roy's criterion, (the multivariate analog to $\underline{w}^2$) was calculated, yielding a value of .35. However, it should be mentioned that Roy's criterion may not be a precise calculation of proportion of variance contributed by a given factor, but it does suffice in giving a rough estimate of proportion of variance contributed by a given factor in a multivariate design.

The nestings of field independence level within Piagetian level did not yield any significant differences in problem solving performance. This would seem to indicate that taking field independence into account within Piagetian level does not provide any additional information for understanding performance on the Productive Thinking problems. It also challenges Witkin's claim that field independence is a cognitive style that shows some kind of consistency across various sorts of intellectual functioning.

Age

Two matrices of intercorrelations, one for boys and one for girls, of all the variables in the study, including age, were obtained. The only significant correlations between age and the other variables are contained in Table 5.

Insert Table 5 here

Age differences appear to be different for boys and girls in the nearly five year age span investigated here, but most impressive is the lack of significant age correlations with the cognitive measures. The only correlation which was to be expected according to theory is the one for boys' scores on the Rod and Frame test: they become less field dependent with increasing age. Noteworthy are the correlations between age and the scoring categories from the Productive Thinking problems. The issue of chronological age as possibly a "better" predictor of problem solving performance than Piagetian level will be considered in the Discussion section.

Problem Scoring Categories

The intercorrelations of the four scoring categories for each problem are of some interest and are shown in Table 6.

Insert Table 6 here

The subjects' scores on the solution scale appear to correlate fairly well with the first scoring category which was intended to assess how well a subject could discriminate the relevant clues from the irrelevant ("The Missing Jewel") and in the second problem how well a subject could pick up on the puzzling or discrepant facts embedded in the presentation of the problem. The correlation coefficients are negative, because on

the solution scale '1' represents an early and complete solution, and '5' represents no correct solution. Generation of ideas for solution appears to be unrelated to correctly solving the problem and, in fact, in the Black House problem number of ideas is an indicator that the subject is not converging on the correct solution. (It should be noted that these two problems are structurally convergent and have only one best or correct solution which satisfies all the constraints of the problem.) The sex differences in degree of correlation in the Black House problem for number of correct analytic choices with number of puzzling facts noticed and solution score may be due simply to sampling error. Scanning the data did not suggest an explanation for this difference.

Discussion

The results obtained in this study indicate that individuals classified as formal operational (or in transition) were generally more competent problem solvers on the Productive Thinking problems than those who were classified as concrete operational. If the problem solver is limited to considering the concrete empirical situation at hand, he will be less able to hypothesize solutions which satisfy the constraints of the problem and transcend the empirical given. For example, some children in the study could 'transcend the empirical given' and would suggest rather fanciful solutions for the disappearance of the black house (e.g. a helicopter lifted the house away), but they failed to satisfy logically the constraints of the problem, such as the detective's different return route, his seeing the sun set and rise

out of the "same" window in Mr. Round's house, and so forth. On the other hand, the formal operational individual can consider problems involving several variables and their interaction; he can entertain hypotheses and deduce inferences from them and systematically evaluate alternatives. The continual decline in egocentrism that accompanies cognitive development also allows the problem solver to adopt different perspectives on the problem, thus making for still further flexibility and decentering in the strategies employed to solve the problem.

It is possible that Piagetian theory best describes and predicts problem solving performance on problems which present a complex, logical deductive structure such as the Productive Thinking problems used here. The Productive Thinking problems are also entirely couched in the verbal medium, in contrast to manipulative problems or problems requiring some kind of specific action to reach a goal-object (Kohler, 1925; Gottschaldt, 1933). With the introduction of the verbal medium, the subject has the additional task of imagining the reality corresponding to the linguistic-symbolic terms of the problem. Conceivably, problems such as the functional fixedness problems or the manipulative WISC subtests, which were related to field independence, would not show a continuous improvement with increasing cognitive development (through equilibration of formal operations), but rather performance on these problems might show a leveling off at the concrete operational stage. (In other words, a ceiling effect might be encountered.) However, this is merely supposition, and further research with Piagetian developmental tasks and these problems is necessary to substantiate such a hypothesis.

In order to ascertain how well Piagetian theory predicts problem solving performance, much more research needs to be done. It is interesting to note that the formal operational tasks presented to the subject are, in fact, problematic situations, in so far as a situation is problematic if the subject cannot make an immediately appropriate response by drawing on his directly repertoire of responses (Oléron, 1969, p. 48). Although the 'scientific' content differs greatly from the Productive Thinking detective problems, some continuity in the kinds of strategies used for both kinds of problems appears to exist. The question becomes whether successful problem solving strategies in complex, multi-step problems are synonomous with logical operations.

The issue of chronological age (CA) as a predictor of developmental differences in problem solving performance should be mentioned. CA may well be an adequate statistical predictor of performance, but it hardly explains anything. When one attempts to satisfy Newell, Simon, and Shaw's demands for a theory of problem solving, then CA fairs rather poorly. The passage of time alone does not explain how problem solving takes place, nor how changes in the conditions of the problem solver or of the problematic task affect problem solving behavior, nor how problem solving skills are learned (developed). CA may be a statistical predictor, but it cannot take the place of a firm theoretical position.

The construct field independence appears to have doubtful implications for complex problem solving performance. The analyses indicate that field independence within each Piagetian level does not affect complex, multi-step problem solving performance as manifested in the

Productive Thinking problems. This does not invalidate the role field independence might have in determining performance on problems which are more perceptually bound and/or relatively non-verbal. The results obtained here, however, cast doubt on the generality of the field independence construct as a 'cognitive style' or as a consistent characteristic of the individual in his intellectual functioning.

The mixed results in field independence for boys and girls within the cognitive developmental framework (in which there are no sex differences) are particularly difficult to explain theoretically. If Witkin's psychological differentiation hypothesis is supposed to correspond with increasing field independence as a child matures, why do the most cognitively mature and complex girls appear to exhibit greater field dependence than their less mature peers (both boys and girls)? The relative field dependence of these girls in the period of formal operations is even more striking in the statistically significant comparison with their less cognitively mature and complex female peers at the transitional or intermediate Piagetian level. In the opinion of the author these results need replication with a larger sample (cell frequencies being rather small in this case) before an adequate theoretical explanation can be advanced. However, it may be that these most cognitively mature teen-aged girls, because they demonstrate formal operational thought, and as a result are less egocentric, become more sensitive to sex role expectations and stereotypes: a reliance upon external cues when a judgment is to be made in an ambiguous situation is expected of "young ladies". The transitional and concrete operational girls, on

the other hand, may be less likely to respond to such (subtle?) social expectations, being more tied to their immediate, empirical reality.

The lack of any clear-cut relationship between field independence and Piagetian cognitive development may prove to be an example of Piaget's own theoretical distinctions between the figurative and operative domains of mental activity. The operative aspect characteristically refers to either overt or internal actions which result in some transformation of reality. Such transformations may be of a logical nature or may be of a physical-action nature as when a baby kicks his crib in order to shake a suspended rattle. In this study an individual's cognitive development rating was based on the logical transformations he was capable of applying to the two Piagetian tasks. In other words, it was primarily the operative aspect of his mental activity that was assessed and is represented in the Piagetian level score used in the analyses.

The figurative aspect refers also to actions, but these actions typically are those in which the child focuses on states of reality rather than transformations of reality. In a sense, the child produces a "copy" of the state of reality by means of a perceptual act, an imitative act, or an internal mental image of a state of reality. The judgment of verticality in an ambiguous situation as in the Rod and Frame test may be essentially a figurative act and does not involve any transformations. Piaget describes perception as "the knowledge we have of objects or their movements by direct and immediate contact, while intelligence is a form of knowledge obtaining when detours are involved" (Piaget, 1960, p. 53). There appears to be no logical or physical

"detour" or transformation involved in the perceptual judgment required in the Rod and Frame test. Consequently, performance on the Rod and Frame test may be relatively independent of the development of logical operations. It has been suggested (Langer, 1970) that the figurative aspect of cognition may have a different developmental curve than the operative aspect. There is also some experimental evidence from Piaget's laboratory that perceptual judgments appear to reach a "ceiling" during concrete operations (Flavell, 1963).

Several analytic links were also postulated between field independence and formal logical thinking or reasoning, and it was hypothesized that on the basis of this analytic emphasis increasing field independence would be associated with more advanced developmental level. However, the supposed similarity in emphasis on analysis in the two theoretical approaches apparently is not the case, as development of logical thought did not necessarily parallel the development of increasing field independence. (The Rod and Frame sex differences illustrate this well.) Pierre Oléron in a review on problem solving has commented on the role analysis may play in problem solving, but he notes that in fact analysis does not correspond to a single psychological activity (1969, p. 65):

> Thus breaking down a whole into its parts, a normal procedure when trying to understand a piece of mechanical apparatus, is different from a regressive search for the logical conditions on which the truth of a proposition depends.

This perspective may well account for the lack of correspondence between increasing field independence with its perceptual focus on breaking down

a whole into its parts and Piaget's theory of development of logical thinking with its emphasis on logical deduction. The kinds of analysis involved in the two theories appear to be on very different levels.

In summary, then, much of Witkin's claim for field independence as a cognitive style, as an index for psychological differentiation, and so forth, is very likely rather inflated insofar as the results obtained in this investigation are concerned. Field independence appears to be more applicable to individual differences in perceptual sets and perhaps is also influenced by extra-intellectual variables such as social expectations, personality correlates, and the like (see Vaught, 1965; Konstadt and Forman, 1965; Solar et al., 1969).

Conclusion

The purpose of this investigation has been to try to understand differences in problem solving performance. The interpretation taken was that one could understand such differences in terms of the development of cognitive structures which were hypothesized to underlie strategies for tackling and solving complex problems. Two structural theories, Piaget's theory of cognitive development and Witkin's theory of cognitive style (field independence), were proposed as possible theoretical bases for such cognitive structures. It was thought that Piaget's development of logical thinking would provide an over-all framework for understanding complex problem solving performance and that Witkin's field independence would provide information about individual differences in problem solving behavior within each Piagetian developmental level. However, this hypothesis was only partially

confirmed. Piagetian developmental level does give us the over-all theoretical framework in which to understand and interpret differences in complex, deductive problem solving performance, but in the problems used field independence does not appear to clarify individual differences in a meaningful way.

We are left with the task of specifying more precisely the nature of the structure presented by a given problematic situation and what kinds of cognitive structures in the individual will best deal with such a problem. It appears again to be an issue of "the match" between what sorts of capacities the individual brings with him and what sorts of 'demands' the problematic situation presents. On the basis of this investigation the author contends that Piaget's developmental theory of logical thinking provides the basis for understanding how an individual deals with problems which present a logical deductive structure as exemplified by the Productive Thinking problems.

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TABLE 1

Cognitive Development Scale

Scale

1 = IA: Beginning of Sensory-Motor

2 = IA/IB: Transitional

3 = IB: Consolidated Sensory-Motor

4 = IB/IIA: Transitional to Concrete Operations

5 = IIA: Beginning of Concrete Operations

6 = IIA/IIB: Transitional

7 = IIB: Consolidated Concrete Operations

8 = IIB/IIIA: Transitional to Formal Operations

9 = IIIA: Beginning of Formal Operations

10 = IIIA/IIIB: Transitional

11 = IIIB: Consolidated Formal Operations

TABLE 2

Means and Standard Deviations of Rod and Frame Scores According to Sex and Piaget Level

Piaget Level	Females			Males		
	No.	M	SD	No.	M	SD
Concrete Operations	12	4.76	3.27	11	4.06	2.48
Transitional	13	4.10	2.50	12	3.66	2.40
Formal Operations	7	7.67	4.88	9	2.26	1.16

TABLE 3

Cell Frequencies for Field Independence Level

Nested Within Piaget Level

Field Independence Level	Piaget Level: Concrete Operations	Transitional	Formal Operations	Row n
Low	9	8	4	21
Medium	9	8	5	22
High	5	9	7	21
Column n	23	25	16	N=64

TABLE 4

Scoring Category Means for Productive Thinking Problems According to Field Independence Level Nested Within Piaget Level

Piagetian Level	Field Indep. Level	"The Missing Jewel" Rel. Clues	Analytic	No. Ideas	Sol. Scale	"The Old Black House" Puzz. Facts	Analytic	No. Ideas	Sol. Scale
Concrete Operations	Low	.33	3.11	4.11	4.33	1.44	2.56	4.00	3.00
	Med.	.67	3.78	3.78	3.78	1.89	2.89	2.44	2.00
	High	1.00	4.60	3.60	3.40	2.00	2.20	3.00	2.60
Transitional	Low	.88	4.50	4.38	3.75	1.38	2.36	2.50	2.25
	Med.	1.25	4.25	4.00	3.13	2.25	3.00	1.63	1.38
	High	1.33	5.00	4.44	2.56	1.78	2.89	2.33	1.78
Formal Operations	Low	1.50	4.00	3.75	2.25	3.25	3.00	4.50	1.75
	Med.	1.20	5.40	2.40	2.40	1.80	2.00	2.40	1.80
	High	1.43	4.86	3.71	2.57	2.14	2.57	3.14	1.43

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TABLE 5

Significant Correlations with Age*

Sex	Variables	
	Field Independence Level (RFT)	Solution Score on "Missing Jewel"
Boys	-.548	-.465
	No. Relevant Clues on "Missing Jewel"	No. Puzzling Facts on "Old Black House"
Girls	.430	.468

* $p < .05$

TABLE 6

Intercorrelations of Scores on Productive Thinking Problems (Separate for Each Sex)

"The Missing Jewel"	(1)		(2)		(3)		(4)	
	boys	girls	boys	girls	boys	girls	boys	girls
(1) No. Relevant Clues	-	-						
(2) No. Correct Anal. Choices	.791*	.656*	-	-				
(3) No. Ideas Generated	.116	-.123	.146	-.217	-	-		
(4) Solution Scale Score	-.850*	-.896*	-.855*	-.751*	-.026	.178	-	-

"The Old Black House"	(1)		(2)		(3)		(4)	
	boys	girls	boys	girls	boys	girls	boys	girls
(1) No. Puzzling Facts	-	-						
(2) No. Correct Anal. Choices	.001	.512*	-	-				
(3) No. Ideas Generated	-.345	-.211	-.011	-.268	-	-		
(4) Solution Scale Score	-.437*	-.482*	-.028	-.568*	.564*[a]	.659*[a]	-	-

[a] These coefficients mean that the more ideas generated, the more slowly and less completely was the solution given.

* $p < .05$

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